Prospectus

The Allocation of Air Ambulance Fleets in the United States

(Technical Topic)

The Role of Science and Politics in Transforming Healthcare Outcomes and Cost for Patients

(STS Topic)

By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

In the United States, an estimated 42.5 million people live outside of a 10-minute fly circle from an air ambulance base (Atlas, 2019). Based on the current allocation of air ambulance bases in 2019, this means that a 20-minute response time, which is imperative in some emergency cases, cannot be achieved for 42.5 million people. Oftentimes, these individuals live in rural areas, meaning there are increased flight distances, creating a lower likelihood of a positive patient outcome and a higher cost incurred by the patient (Alanazy, et. Al, 2019). In the technical aspect of my thesis, I will be creating an optimization model using a Greenfield approach for the allocation of air ambulance fleets across the United States to lower air ambulance travel times and costs to patients.

In addition to the current 10-minute fly circle issues within the United States, more than 80 million people can get to a Level 1 or Level 2 trauma center within an hour only if they are flown by helicopters. This hour, coined the "Golden Hour" is essential for lowering mortality and morbidity rates (AAMS, 2019). Studies show that a prehospital time of less than one hour can greatly increase the patient outcomes after severe head trauma, intra-abdominal bleeds, and severe thoracic injuries (Tien, et. Al, 2011; Clarke, et. Al, 2002; Clevenger, et. Al, 1988). This is significant, especially in rural communities where patients are 14% more likely to die from trauma than patients in the urban U.S (Jarman, et. Al, 2016). Our model hopes to improve patient outcomes by lowering the distance required to travel to hospitals, thus ensuring patients can reach a medical facility within one hour of disease or injury. In regards to other patient burdens, over the past ten years there has been a very significant increase in costs for both helicopter and fixed-wing air ambulance trips across the United States. The average price of an air ambulance trip increased substantially over the 10-year period, rising 144% (from $11,414 in 2008 to

$27,894 in 2017) for helicopters and 166% (from $15,684 in 2008 to $41,674 in 2017) for planes (Hargraves, et. Al, 2019). With a current median price of $36,400 for helicopter air ambulances, these costs are often too high for patients to bear (Bluth, 2019). Especially with nearly three quarters of the patients transported covered by Medicare, Tricare, and Medicaid which on average cover $6,500, the price of air ambulances can put a high cost burden on the patient. On top of this, for those in the rural United States, it is estimated that 12.3% of people in completely rural counties lack health insurance at all (Day, 2019). Through optimizing these air ambulance fleets, our goal is to cut down on the variable costs associated with air ambulance travel, such as fuel, thus decreasing costs incurred by the patients.

In the optimization model, we will utilize a Greenfield approach to obtain maximal population coverage approach based on demand determined in our data analysis. As stated above, the goal is to lower the mission time and cost for air ambulances to transfer the patients to the hospital. In my thesis, I will analyze the impact of the science and politics in the evolution of the healthcare system in the United States over the past fifty years through the lens of the air ambulance industry. This work will help identify the key areas where science has impacted the healthcare industry and provide policy changes to the Medicare and Medicaid system that better serve the patient population.

Technical: The Allocation of Air Ambulance Fleets in the United States

A Greenfield approach will be taken to develop a framework for optimizing air ambulance locations. This means our model will not account for the current layout of air ambulance fleets and allows a new allocation to be created (Brown, 2015). Using the Greenfield approach an optimization model will be created to allocate the air ambulance fleets so maximal population coverage is achieved within a response time constraint to better serve the demand of the United States population. To obtain maximum coverage to patients, the model will be developed through the use of maximal covering location problem (MCLP) to allocate air ambulance bases such that the population is a desired service distance away from an air ambulance base. We will first apply this approach to develop an optimization model for the state of Virginia. As our model evolves and is tested against the current air ambulance allocation and mission times, we will begin to expand the optimization model to other states across the country. Finally, we will complete a total optimization model for the entirety of the United States, with the goal of decreasing the distances needed for air ambulances to travel, thus lowering mission time and costs for patients.

Our optimization model will be following a methodology similar to the one done by Røislien et. al. in Norway (Røislien, et. Al, 2017). This model works by finding the maximum population that can be covered within a specified service distance given a limited number of bases, through the use of relatively simple mathematical equations (Church, 1974). The model also allows us to determine the least number of bases needed to cover a certain amount of the population. The MCLP needs a measure of population density and a measure of the time an air ambulance mission takes. Instead of using population density, we will use the incidence of stroke, heart attack, and trauma by county in the state of Virginia. Stroke, heart attack, and trauma are three conditions that need immediate care which air ambulances commonly provide. Using the incidence of those three conditions will provide a better measure of how many people in each county will need to use an air ambulance, as opposed to using the entire population density of that county. The total mission time of an air ambulance, including pre-flight prep time, flying to the patient, prepping the patient for ambulance travel, and flying to the hospital, will be used as a time constraint for our model. Using the total mission time instead of just the in-air flight time establishes a better measure of how long it will take for the patient to get care. Our total mission time constraint will be one hour, allowing us to ensure the U.S. population can receive medical care within an hour of injury or disease. Using these parameters, we would be able to figure out how to allocate ambulance bases to maximize the population covered within a mission time constraint.

As stated above, maximizing access subject to the time constraint of one hour, allows air ambulances in our optimization model to reach healthcare facilities within the "Golden Hour." To measure the time constraints, we will gather the above data along with the average helicopter speed and mission time in various counties across the state of Virginia. To determine these average time constraints, a historical review over the past five years will be used to find the averages in each of the counties in the state of Virginia. These counties will each be under different time constraints based on geography and distance typically traveled. Once this data is collected, the optimization of the air ambulance fleets will be established to best serve the needs of each county's population.

Through optimizing air ambulance fleet locations within a given time constraint it will reduce mission times, thus improving patient outcomes and lowering costs associated with air ambulances. As stated above, in certain emergency situations, a response time of twenty minutes is needed to ensure patient mortality. In addition, access to hospitals across the rural United States continues to diminish as hospitals close. Since 2005, 174 hospitals have closed and another 430 are at risk, signifying a major issue within the healthcare system (Stone, 2020). In a study conducted at the University of Washington, it was found that while the closings of urban hospitals had no impact on their surrounding communities, rural closings caused their populations - which have limited access to health care and other services - to see mortality rates rise 5.9 percent (McCausland, 2019). As these at-risk hospitals begin to close, the access to healthcare will continue to diminish for rural communities and the importance of air ambulances for positive patient outcomes will increase.

My technological innovation of optimizing air ambulance fleet locations relates to my STS topic of analyzing the role of science and politics in transforming healthcare outcomes and costs for patients by focusing on the human aspect of the air ambulance industry. We want to improve access to healthcare through the utilization of scientific techniques and methods. This improved access based on demand transforms the healthcare outcomes for patients needing ambulance services. In addition, identifying ways to lower variable costs associated with air ambulance travel lowers the costs needed for services for the patients. Hopefully, this leads to public and private air ambulance fleets lowering the costs to patients, thus reducing the surprise billing currently associated with the industry.

Science and Politics in Transforming Healthcare Outcomes and Cost for Patients

For the STS aspect of my thesis, I will be exploring the role of science and politics in transforming healthcare outcomes and costs for patients. I hope to illustrate how changes in technology and politics impact the healthcare industry by conducting a thorough analysis on the air ambulance industry. Through a historical case study analysis of the technologies and systems that have lowered morbidity rates in the air ambulance industry, I will show how technological innovation directly improves patient outcomes. This will provide an example of how science and innovation directly impact the human dimension of a system. In a policy analysis on the use of civilian air ambulances since 1970, I will draw a connection between the role of politics in the costs associated with the healthcare industry. Specifically, I want to illustrate where changes in the policies for Medicare and Medicaid patients could be made in order to lower the costs for the patients transported by air ambulances.

To identify the role of science and politics in transforming healthcare outcomes and cost for patients, I will utilize the framework of co-production to draw conclusions from my research. Co-production can be defined as the idea that society and science evolve together (Jasanoff, et. Al, 2004). Co-production occurs when consumers (society) are engaged in the development of a service or product, thereby helping to ensure quality and enhance value (Turakhia, et. Al, 2017). Within healthcare, co-production can be applied to improving patient outcomes and care based off of their experiences and implementing changes to technology based off of the patient's inputs.

To study a technology or system through the framework and pathway of co-production, there are four main instruments to developing the framework: making identities, making institutions, making discourses, and making representations (Jasanoff, et. Al, 2004). Making identities takes inputs from various stakeholders on how a technology or system is defined. Making institutions analyzes the institutions that come out of a new technology and how to regulate this new system. Making discourses identifies public needs on the tolerable and intolerable sections of the new technology. Lastly, making representations analyzes how political and cultural influences have shaped the use of the technology over time (Jasanoff, et. Al, 2004). Through the use of this framework, I hope to establish how science and politics have shaped the healthcare industry, with a specific dive into the air ambulance industry. I hope to illustrate that the current policies are creating costs that are too high for patients reliant upon systems such as Medicare and Medicaid. In addition, I hope to illustrate that innovation in the air ambulance services industry have created lower morbidity and mortality rates.

The advancement and development of new scientific and healthcare technologies throughout the industry has been essential for lowering mortality rates within the United States. Specifically, increased access to care and transportation to medical facilities has greatly improved these rates over the past fifty years. In 1970, the mortality rate in the United States was 9.516 per 1,000 people, while in 2019, the rate was 8.782 per 1,000 people (Macrotrends, 2019). This is a strong indicator that overall health and the healthcare system in the United States has improved through scientific advancements. Through the use of co-production, I will identify and make discourses that have led to the advancement of technologies within the air ambulance industry.

Health systems in the United States are designed to allow policymakers to increase the populations health benefits through incentivizing individuals to use more services through the use of increased insurance coverage, policies to improve quality of care, and accessibility of healthcare services (Cinaroglu, 2018). Policymakers have an incredible impact on the quality and access to care an individual can receive in health systems in the United States. However, they also have a huge impact on the costs associated with these healthcare needs. Through the use of co-production, I hope to identify how policymakers have or have not established quality care within the air ambulance industry. I will do this by identifying and making representations that illustrate how cultural and political changes have allowed for scientific improvement over the past fifty years.

Healthcare Outcomes in the Air Ambulance Industry

To narrow the focus of the role of science in transforming healthcare outcomes, I will conduct analysis on the current and historic healthcare outcomes of patients who are transported via air ambulances. By analyzing the morbidity and mortality rates for patients transported by air ambulances, I will show how technological innovation impacts humans and their health. I will illustrate the impact of technological innovation in the air ambulance industry through the use of meta-learning. Meta-learning attempts to explain the progress of technology over time by relating innovation to learning via scaling, doing, planning, and sharing (Butler, 1988). This theory believes in the idea that innovation is a probabilistic process and that there is a mutual dependence for growth between product and process technology over time. Through this theory, I can uncover how the air ambulance industry has evolved over time through technical innovation and how it has allowed air ambulances to lower morbidity and mortality rates. In addition, I will be able to identify what scientific improvements they specifically made that have aided in their transportation capabilities. Overall, in this research, I want to show how scientific innovations directly correlate with more positive patient outcomes.

With roughly 1 out of every 1,000 people in the United States needing air ambulance transportation services every year, the need for improvements in technology has been essential for years (AAMS, 2019). Technology and innovation have driven mortality rates for patients transported via air ambulances down compared to those transported in ground ambulances. For example, in 2014, patients transported by air ambulances were 57% less likely to die than those transported by ground ambulances (Michaels, et. Al, 2019). In my research, I will identify the equipment and technology that has driven the air ambulance industry to become more successful over the past fifty years.

Insurance and Cost in the Air Ambulance Industry

Through analysis of the current policies regarding Medicaid and Medicare in the Air Ambulance Industry, I hope to narrow my focus of the role of politics in transforming healthcare cost. Medicare is a federal program that provides health coverage for people over the age of 65 or under 65 years old with a disability, regardless of income. Medicaid is a state and federal program that provides health coverage if you are in a low-income bracket (Medicare Interactive, 2019). Although there are protections for patients with Medicaid and Medicare for hospital bills, there is very little protection on the transportation to the hospital (AAMS, 2019). In the air ambulance industry, there are often high costs and surprise bills associated with air ambulance travel. In one report based on 2017 data, found that the median air transport trip was $10,200. During 2017, Medicare on average pays about $6,500 per transport and Medicaid pays around $3,000 per ambulance trip, often leaving costs for patients that they cannot pay (Frieden, 2019). In certain states, the coverage for Medicaid can be even lower based off of that states policies. This indicates that there is a room for change for policies revolving around ambulance transportation.

Currently, there are no proposals circulating in the United States government to address the high cost and surprise bills to air ambulance patients (Day, 2019). With only 59% of the Medicare costs being covered in 2015 and about 75% of air transport patients being uninsured or on Medicare and Medicaid, it shows that the current policies are not providing proper coverage to its most likely patient for air ambulance services (Bluth, 2019; AAMS, 2019). This is a disservice to the United States population and is going to continue if there are not policy changes made to the Medicare and Medicaid systems.

Research Question and Methods

I will explore the question: How does science and politics shape healthcare outcomes and cost in the United States? I will analyze this research question through the framework of co-production. Through the use of the co-production framework, I will conduct research on the healthcare industry by examining historical case studies and engaging in policy analysis. The historical case study analysis will be conducted to understand the relationship between scientific improvements within the air ambulance industry and healthcare outcomes of patients over a finite period of time. I will collect this data from various sources starting in 1970, when civilian air ambulances were first used in the United States, to 2019 (Grabenstein, 2019). I will gather data on both the morbidity and mortality rates of the patients to understand how the air ambulance industry has evolved from its beginning in 1970. I hope to identify the key scientific improvements and technologies that have shaped this change. This data will then be analyzed through the four instruments of the co-production framework. Analyzing the scientific improvements that have improved morbidity and mortality rates within the air ambulance industry provides a snapshot of how medical innovation has impacted the United States over the past fifty years.

A policy analysis will help illustrate the various laws and regulations that have impacted air ambulance and healthcare costs in the United States since 1970, the inception of civilian air ambulances. I will base my policy analysis off of the framework used by Cinaroglu where it is a pathway analyzing policy and health outcomes over a finite period of time (Cinaroglu, 2018). Since there is an abundance of healthcare policy change since 1970, I have chosen to narrow my focus to only the air ambulance industry. I will analyze the impact policymakers have on costs incurred by individuals, with a specific dive into the costs associated with air ambulance services for Medicaid and Medicare patients across the United States.

Conclusion

In the United States, more than 80 million people can get to a Level 1 or Level 2 trauma center within an hour, only if they are flown by helicopters. In allocating air ambulance fleets across the United States through an optimization model by maximal population coverage within a response time constraint it should lower average mission times, thus improving patient outcomes and lowering costs. Through the analysis of the impact of science and innovation on the healthcare industry, I hope to identify the key characteristics that drive innovation in the healthcare industry and illustrate how these innovations positively impact patients. In analyzing the politics that impact the air ambulance industry, I hope to provide a lens into the issues regarding the Medicaid and Medicare system and identify changes that will lower costs incurred by patients. Through current and historic policy analysis, I hope to illustrate how state and federal governments could change these policies to lower costs incurred by individuals. In my research, I will perform a historical case study and policy analysis and apply my findings to a co-production framework in order to identify how politics and science have impacted the healthcare world.

Bibliography

AAMS Publishes Findings of Air Medical Cost Study. (2019, December 10). Retrieved November 3, 2020, from AAMS website: https://aams.org/aams-publishes-findings-air-medical-cost-study/

Alanazy, A. R. M., Wark, S., Fraser, J., & Nagle, A. (2019). Factors Impacting Patient Outcomes Associated with Use of Emergency Medical Services Operating in Urban Versus Rural Areas: A Systematic Review. *International Journal of Environmental Research and Public Health*, *16*(10), 1728. https://doi.org/10.3390/ijerph16101728

Atlas & Database of Air Medical Services 17th Annual Edition A National Database Showing Base Locations for Rotor and Fixed Wing Air Medical Services. (n.d.). Retrieved from http://www.adamsairmed.org/pubs/atlas_2019.pdf

Bluth, R. (2019). Why Air Ambulance Bills Are Still Sky-High. Retrieved from NPR.org website: https://www.npr.org/sections/health-shots/2019/06/14/732174170/why-air-ambulance-bills-are-still-sky-high

Butler, J. (1988). Theories of Technological Innovation as Useful Tools for Corporate Strategy. *Strategic Management Journal*, *9*(1), 15-29. Retrieved December 6, 2020, from http://www.jstor.org/stable/2485999

Brown, K. (2015). Benefits of the Greenfield Approach | The Information Umbrella. Retrieved from aimblog.uoregon.edu website: https://aimblog.uoregon.edu/2015/06/30/benefits-of-the-greenfield-approach/

Church, R., & ReVelle, C. (1974). *The maximal covering location problem*. Papers in Regional Science. https://link.springer.com/article/10.1007/BF01942293.

Cinaroglu, S. (2018). Politics and health outcomes: A path analytic approach. *The International Journal of Health Planning and Management*, *34*(1), e824–e843. https://doi.org/10.1002/hpm.2699

Clarke , J. R., Trooskin, S., Doshi, P., Greenwald, L., & Mode, C. (2002). *Time to laparotomy for intra-abdominal bleeding from trauma does affect survival for delays up to 90 minutes*. The Journal of trauma. https://pubmed.ncbi.nlm.nih.gov/11901314/.

Clevenger, F. W., Yarbrough, D. R., & Reines, H. D. (1988). Resuscitative thoracotomy: the effect of field time on outcome. The Journal of trauma. https://pubmed.ncbi.nlm.nih.gov/3352006/.

Day, J. (2019). Bureau, U. C. (n.d.). Health Insurance in Rural America. Retrieved from The United States Census Bureau website: https://www.census.gov/library/stories/2019/04/health-insurance-rural-america.html#:~:text=Residents%20of%20rural%20counties%20still

Differences between Medicare and Medicaid. (n.d.). Retrieved from Medicare Interactive website: https://www.medicareinteractive.org/get-answers/medicare-basics/medicare-coverage-overview/differences-between-medicare-and-medicaid#:~:text=Medicare%20is%20a%20federal%20program

Frieden, J. (2019, November 27). Medical Air Transport Providers Concerned About Underpayment. Retrieved November 3, 2020, from www.medpagetoday.com website: https://www.medpagetoday.com/publichealthpolicy/medicare/83624

Gradenstein, K. (2019). Air-Medical Services: Then and Now. (n.d.). Retrieved from EMS World website: https://www.emsworld.com/article/1223054/air-medical-services-then-and-now#:~:text=The%20first%20U.S.%2Dbased%2C%20Federal

Hargraves, J & Bloschichak, A. (2019). Air Ambulances – 10 Year Trends in Costs and Use. (n.d.). Retrieved from HCCI website: https://healthcostinstitute.org/emergency-room/air-ambulances-10-year-trends-in-costs-and-use

Jasanoff., & Shei, L., (n.d.). *States of Knowledge The co-production of science and social order Edited by Sheila Jasanoff Ordering knowledge, ordering society*. Retrieved November 3, 2020, from http://sheilajasanoff.stsprogram.org/wp-content/uploads/S.-Jasanoff-States-of-Knowledge-Ch.-2-Ordering-Knowledge-Ordering-Society.pdf

Jarman, M., Castillo, R., Carlini, A., Kodadek, L., & Haider, A. (2016). *Rural risk: Geographic disparities in trauma mortality*. Surgery. Retrieved from: https://pubmed.ncbi.nlm.nih.gov/27506860/.

McCausland, P. (2019). Rural hospital closings lead to more deaths, study finds. (n.d.). Retrieved from NBC News website: https://www.nbcnews.com/news/us-news/rural-hospital-closings-cause-mortality-rates-rise-study-finds-n1048046#:~:text=That%20could%20have%20real%20implications

Michaels, D., Pham, H., Puckett, Y., & Dissanaike, S. (2019). Helicopter versus ground ambulance: review of national database for outcomes in survival in transferred trauma patients in the USA. *Trauma Surgery & Acute Care Open*, *4*(1), e000211. https://doi.org/10.1136/tsaco-2018-000211

Puja, Turakhia, & Combs, B. (2016). Using Principles of Co-Production to Improve Patient Care and Enhance Value. *AMA Journal of Ethics*, *19*(11), 1125–1131. https://doi.org/10.1001/journalofethics.2017.19.11.pfor1-1711.

Røislien, J., van den Berg, P. L., Lindner, T., Zakariassen, E., Aardal, K., & van Essen, J. T. (2016). Exploring optimal air ambulance base locations in Norway using advanced mathematical modelling. *Injury Prevention*, *23*(1), 10–15. https://doi.org/10.1136/injuryprev-2016-041973

Stone, W. (2020). Getting Health Care Was Already Tough In Rural Areas. The Pandemic Has Made It Worse. (n.d.). Retrieved from NPR.org website: https://www.npr.org/sections/health-shots/2020/10/07/920587019/getting-health-care-was-already-tough-in-rural-areas-the-pandemic-has-made-it-wo

Tien, H., Jung, V., Pinto, R., Mainprize, T., Scales, D., & Rizoli, S. (2011, June 1). *Reducing Time-to-Treatment Decreases Mortality of Trauma Patients with Acute Subdural Hematoma*. Retrieved from doi:10.1097/SLA.0b013e318217e339: https://insights.ovid.com/annals-surgery/ansu/2011/06/000/reducing-time-treatment-decreases-mortality-trauma/20/00000658.

U.S. Death Rate 1950-2019. (2019). Retrieved from Macrotrends.net website: https://www.macrotrends.net/countries/USA/united-states/death-rate